Evaluating the abiotic and biotic characteristics of Larks Lake to predict the success of a larger fishes population

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Abstract

Larks Lake, Emmett County, Michigan is a small marl lake with a littoral zone that extends throughout the depth of the lake. The Larks Lake association is interested in preserving the game fishes populations that appear to be in decline (Tip of the Mitt, 2006). A study done 20 years ago identified the lake as not able to support a healthy game fishes population (Anderson and Ridley, 1993). Through minnow trapping, and seining we observed the fishes communities throughout the lake specifically in two habitats, reedy and sandy. We also constructed a point data map of the available fish structure in the lake. Despite Anderson and Ridley's (1993) statement that the lake could only sustain a limited game fishes population, we found an increase in the game fishes of the lake. We also sampled zooplankton to evaluate the success of an increase in bluegill (*Lepomis macrochirus*) in the lake, and found that the lake would be able to support a maximum growth rate of larval bluegill (Dai, 1997). We determined that there has been a change in the fishes communities of Larks Lake, and that the scheduled stocking of 3500 bluegill in September 2013 will be successful.

Introduction

Calcium carbonate ($CaCO_3$) is a key ion in lake systems and originates from the leaching of rocks and soil in the catchment area of a lake (Pelechaty *et. al.,* 2013). Marl lakes have an abundance of calcium carbonate that precipitates out both in charophytes and in the sediments (Pelechaty *et. al.,* 2013). High pH levels also contribute to the precipitation of calcium carbonate, and the presence of calcium carbonate and bicarbonate (HCO_3^-) ions affect the buffering capacity of lakes (Pelechaty *et. al.,* 2013). Charophytes have a large role in the precipitation of carbonates in the littoral zone, and most of these species are limited to clear, alkaline fresh water lakes with a low trophic status (Pelechaty *et. al.,* 2013).

Macrophytes and large woody debris (LWD) provides important fish structure for fishes. Small bluegill (*Lepomis macrochirus*) (60-100mm) depend on macrophyte availability for shelter from predation (Pothoven *et. al.,* 1999). Larger bluegill however have a positive correlation with decreased macrophyte abundance possibly due to a lack of competition from smaller bluegills (Pothoven *et. al.,* 1999). Young of the year (YOY) largemouth bass (*Micropterus salmoides*) are more dependent on macrophyte abundance due to frequent predation of large largemouth bass on (YOY) largemouth bass (Pothoven *et. al.,* 1999). LWD is an important habitat structure, especially for largemouth bass (Sass *et.al.,* 2011), and its presence can influence spawning habits and abundance. An increase in LWD can positively impact the game fishes population of a lake (Sass *et. al.,* 2011).

Zooplankton are an important food source for small forage fishes, and often juvenile fishes (Cailliet *et. al.,* 1986). An increased density of zooplankton correlates with an increased growth rate of larval fish (Dai, 1997). It is important to understand the trophic cascade when introducing new populations of fishes, and to determine the availability of a food source for the introduced population. Dai (1997) found that increased levels of zooplankton increased growth rates of larval bluegill, and required a density of 50-75 zooplankton crustaceans per liter to reach maximum growth rates.

The Larks Lake association is interested in the health of their lake, and its game fishes population. The lake association has a consistent volunteer lake monitoring program through Tip of the Mitt watershed counsel. Recently the association applied for a grant to stock fishes. This grant was denied due to a lack of an adequate map of LWD. Through fundraising, the association was able to save enough money for the stocking of 3500 bluegill (*Lepomis macrochirus*) in the summer of 2013. This stocking was delayed due to a weather related fish kill at the stocking company and should occur in September 2013.

Twenty years ago two students from the University of Michigan Biological Station did a survey of the fishes populations of the lake (Anderson and Ridley, 1993). Given their fishes data and the determined lack of productivity, Anderson and Ridley (1993) determined that an addition of conifer trees and brush piles would over time improve nutrient levels, and increase fish structure, over time increasing fishes populations. This suggestion has been followed to an extent by the Larks Lake community sinking Christmas trees and 7 boats in the lake (Hammond 2013, pers. comm.). The local anglers have noticed a correlation with increase in fish structure and location of fishes and these areas have become popular fishing locations (Hammond 2013, pers. comm.).

A further increase in large woody debris and other fish structure would likely increase fishes populations. As lakeshore residential development increases, the riparian zone changes and LWD is often removed and further addition is halted (Gaeta *et. al.*, 2010; Sass *et. al.,* 2006). This loss of LWD can alter the growth of fishes and populations of fishes (Gaeta *et. al.,* 2010) due to changes in diet and increased cannibalism (Sass *et. al.,* 2006). As there continues to be an increase in development to the shoreline (Tip of the Mitt, 2006) the riparian zone changes from forested area to fertilized lawn (Christensen *et. al.,*1996). Larks Lake is in general gently used, but development does continue to increase on the shoreline. The lake association and Tip of the Mitt (Tip of the Mitt, 2006) has noticed a decline in fishes populations and this has caused concerns. LWD levels should continue to be added in effort to increase in the lake and in the littoral zone.

We set out to answer a series of questions about Larks Lake in order to predict the success of a larger fishes population. We determined the trophic status of Larks Lake to determine the availability of nutrients, and algal populations. We made a point data map of the rooted macrophytes and large woody debris to determine density of fish structure. We calculated density of zooplankton to identify the availability of food for small forage fishes, and planktivores. We compared the lake fishes population of today to the lake fishes population observed by Anderson and Ridley (1993) twenty years ago.

Methods

Overview

Larks Lake is located in Emmet County, Michigan and is a shallow unproductive marl lake (Figure 1). The lake has a surface area of 239.139 hectares, and a watershed area of 1877.741 hectares. In 1993, the lake was recorded to have 45 cottages (Anderson and Ridley, 1993). This has since increased to 54 (Tip of the Mitt, 2006). The lake is shallow having a maximum depth of 2.38m, and an average depth of 0.8m (Tip of the Mitt, 2006). The substrate is mucky and consists largely of marl (Tip of the Mitt, 2006), a calcium carbonate precipitation and deposition in the substrate (Wetzel, 2001). The lake is used largely for boating, fishing, recreation (e.g. swimming) and for water withdrawal (Tip of the Mitt, 2006). Larks lake is heavily utilized, and monitoring the status will help preserve its natural beauty for years to come.

Water Chemistry

We began by conducting a series of water chemistry and quality measurements to determine trophic status index. We sampled water from the surface for alkalinity, total phosphorus, soluble reactive phosphorus, ammonium, and nitrate tests which were completed at the University of Michigan Biological Station Chemistry Lab. We placed the samples into acid washed bottles and kept them on ice until testing. We also passed 112ml of water through a 0.45µm HA Nitrocellulose chlorophyll a filter using a syringe and submitted it to the UMBS Chemistry Lab for analysis of chlorophyll a levels. We took dissolved oxygen (DO) and temperature measurements using a YSI DO meter at the surface, 0.5m and every half meter thereafter until the bottom of the lake, 2.4m. We measured pH using an Accumet AP Series Handheld pH/mV/Ion meter at the surface of the lake. We took conductivity measurements using a YSI salinity, conductivity, and temperature meter at the surface, 0.5m and every half meter thereafter until the bottom of the lake, 2.4m. Using a photometer we measured percent surface irradiance to confirm data taken with the Secchi disk we did this by taking measurements at the surface, 0.5m and every half meter thereafter until the bottom of the lake 2.4m. We took all of our samples and measurements from a boat anchored at 45º36.26‘N 84º55.55‘W. We used Carlson's (1977) trophic status index (TSI) equations to determine the trophic status of Larks Lake.

Fishes

To measure the fishes of Larks Lake we seined using a 3.0m seine, a 4.3m seine, and a 6.1m bag seine, we set minnow traps at all four sites, and took habitat transects so we could compare sites. We seined with the 3.0m seine with 2 hauls at each site, with the 4.3m seine twice at each site, and with the 6.1m bag seine three times at each site, each seine haul was approximately 20 seconds. We evaluated catch per unit effort (CPUE) by seine haul of fish caught per meter of seine and used a t-test to compare habitat types of sandy and reedy. We set the minnow traps out for a total of 9 days at sites A,B, and C, and at site D (Figure 1) for a total of 7 days. The minnow traps were set in lines of 5 with an average of 15.3m, the minnow traps were spaced an average of 3.825m apart. We determined distance between traps by changes in habitat. We baited the minnow traps with dog food and reset them every 48 hours. We evaluated CPUE by 24 hours for the minnow traps and determined total abundance, species richness and Shannon diversity index for each site and for each habitat type, we then used a t-test to compare habitat types. We calculated average CPUE per meter for seines and compared this data to CPUE per 48 hours in minnow traps.

Zooplankton

We dragged a Wisconsin net for approximately 1065m at the surface, and from bottom to top (2.4m) twice to get a quantitative sample of the zooplankton of the lake this gave us a total sample of 121.0L. In order to get a quantitative sample we counted the numbers of rotifers, copepods, and cladocera in 1.2ml of the sample, we then extrapolated the density of zooplankton in the lake comparing this data to the volume of water sampled.

Habitat Mapping

In order to accurately estimate the presence fish structure in the lake we made a point data map of the large woody debris (LWD) and rooted macrophytes in the lake. John Hammond, a local angler, took us out in his fishing boat and pointed out areas of LWD and rooted macrophytes in the lake. We recorded these points using a Garmin 62 GPS unit. This point data map was overlaid using ArcGIS with the Tip of the Mitt's vegetation and substrate maps created in 2009. We then separated fish structure types into LWD, and rooted macrophytes and divided this by the surface area of the lake to get a density of fish structure.

Results

Habitat Mapping

We found an density of 7.08 logs/km^2 within the lake (Figure 1). We found the greatest density of LWD surrounding Pioneer Park (Site A), and very little density of fish structure in the southern half of the lake. We determined that due to our sampling method, calculating an average density of rooted macrophytes based on our point data map would be inaccurate.

Fishes

Using seines we caught a total of 267 individuals with 8 hauls, this included 6 different species (Figure 2). Our average CPUE was 2.5 fish per meter of seine (Figure 3). Our average CPUE for the 6.1m bag seine was 8.6 fish, our average CPUE for the 3.0m seine was 12.5 fish, and our average CPUE for the 4.3m seine was 1.8 fish. We caught the greatest abundance of fishes in the reedy habitats, sites A and B, and had the greatest species richness in the reeds. This difference was not significant (T=1.3684, df=13, p=0.1944).

Our average CPUE based on minnow traps was 4.7 fish per 48 hours in the reeds, sites A and B (Figure 10), and 2.22 fish per 48 hours in the sand, sites C and D (Figure 3), the difference in CPUE between our two sites was insignificant, (T=1.4228, df=12, p=0.1887). We found the greatest abundance of fishes in the reedy habitats and the greatest species richness in the sandy habitats (Figure 3). Largemouth bass (*Micropterus salmoides*) total abundance is significantly different between reeds and sandy habitat, (T=2.0136, df=10, p=0.059).

Our fishes total abundance and species richness varied by habitat and by method of capture. We caught the greatest abundance of fishes in the reedy habitats (Figure 2), and the greatest species richness in the reedy habitats (Figure 3). Though our differences were not significantly different, given our observations and small sample size we can report a difference in fish communities between reedy habitats and sandy habitats in Larks Lake.

Water Chemistry

Our water chemistry and quality samples gave us a trophic status using Carlson's (1977) trophic status index (TSI) equations. Larks Lake had an alkalinity of 92.0 mg-$CaCO_3$/L at the surface. Surface total phosphorus level was lower than previous levels measured by the Tip of the Mitt (Figure 4). Our soluble reactive phosphorus levels were 1.4µg/L at the surface. Ammonium (NH_4) levels at the surface were 3.5µg/L. Nitrate levels decreased compared to previous years (Figure 5), however this could be due to decreased nutrients in late summer (Dodds and Whiles, 2010). We found 2.4µg/L chlorophyll a at the surface of Larks Lake.

Larks Lake is completely in the photic zone and does not stratify, even at the deepest point of the lake. The temperature was constant, 21.3ºC, throughout the water column. Dissolved oxygen levels remained relatively constant through the water column and dropped approximately 60% from surface values at the bottom (2.4m) of the lake (Figure 6). The level of dissolved oxygen at the surface of the lake is consistent with past surface measurements of the lake (Figure 7). Levels of pH were slightly higher than previous measurements (Figure 8). Our measurement of specific conductivity was consistent with past measurements (Figure 9) and represents a slight decrease in conductivity likely due to our measurements being taken in late summer (Dodds and Whiles, 2010). The levels of conductivity throughout the water column were very consistent only changing 0.6 µS from surface to bottom (2.2m) (Figure 10). Our photometer measurements show a decline in percent surface irradiance through the water column, and 17% surface irradiance at the bottom (2.3m) of the lake (Figure 11). Our Secchi disk was still visible at the bottom of the lake (2.7m) supporting the photometer data.

Zooplankton

Zooplankton density in Larks Lake included 85 rotifer per liter, 8.33 copepods per liter, and 2.5 cladocera per liter (Figure 12).

Discussion

We sampled LWD abundance to determine the availability of habitat structure in the lake, and found a density of 7.08 logs/km^2. Sass *et. al.* (2011) did not find any significant changes in lake trophic structure, or fish behavior with an increase in LWD. The local anglers of Larks Lake have observed increased large game fishes populations surrounding LWD habitats in the lake

(Hammond, 2013, pers. comm.), and fish in areas with increased structure. A change in littoral LWD based on lakeshore residential development has negative effects on largemouth bass growth rates, increasing growing time until entry into the fishery (356mm) by 1.5 years (Gaeta *et. al.,* 2011). Continuing to monitor LWD density will help insure that largemouth bass enter the fishery (356mm) as fast as the lake will allow.

Our sampling of Larks Lake's fishes gave us data comparing habitat structure to determine if an increase in structure would increase the fishes populations. We did not find a significant difference between reed habitat and sand habitat for total abundance CPUE of minnow traps (T=1.4228, df=12, p=0.1887). This could be due to the bias of minnow traps based on size range and taxa (Layman and Smith, 2001), however the difference between minnow trap CPUE and seine CPUE in the reeds is not significantly different (T=-0.3951, df=7, p=0.7046). This is not surprising because an increase in habitat structure correlates with and increase in fishes populations (Sass *et. al.,* 2006). Largemouth bass also prefer a presence of LWD when spawning (Lawson *et. al.,* 2011), and an increase in residential development on the shoreline has a negative relationship with LWD presence. Our reedy habitats had less shoreline development than sandy habitats. We only found yellow perch (*Perca flavescens*) in minnow traps in the sandy habitats, however the opposite was true for seining, we found the vast majority of yellow perch in the reedy areas.

Zooplankton are important to the availability of increased fishes populations (Dai, 1997). As zooplankton increases so does the density of larval bluegill (*Lepomis macrochirus*) (Dai, 1997). Dai (1997) used mesocosms to observe the growth rate of larval bluegill depending on zooplankton crustaceans. Larval Bluegill reach their maximum growth rate at approximately

50-75 crustaceans/L (Dai, 1997). This data is important because of the Larks Lake association's plan to stock Bluegill in the summer of 2013. Though the Larks Lake association is planning on stocking fish that are between 6 and 9cm if this population survives, which likely it will, they will reproduce and it is important to evaluate the likelihood for survival of future generations.

Anderson and Ridley (1993) determined that Larks Lake was unable to support a healthy game fishery. They sited the lack of vegetation for both spawning and refuge, and lack of food availability as the reason behind this lack of fishery support (Anderson and Ridley, 1993). They suggested the increase in fish structure by the addition of LWD, and an increase in fishes populations by the stocking of an age class that feeds on young perch and cyprinids (Anderson and Ridley, 1993). These suggestions have been followed to an extent by the Larks Lake association. LWD has been increased in the lake, and a stocking is scheduled for September 2013 (Hammond, 2013, pers. comm.). Anderson and Ridley (1993) found a white sucker (*Catostomus commersonii*) and yellow perch (*Perca flavescens*) dominated fish community (Table 1), while we found a smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and spottail shiner (*Notropis* hudsonius*)* dominated community (Table 2). This change represents a game fish population increase in the past 20 years.

Lark's Lake has an alkalinity of 92.0mg $CaCO_3$/L. This value is characteristic of a lake nonsensitive to increased acid (Shaw *et. al.*, 2004). Our pH level was 9.03 which is highly alkaline (Michaud, 1991). This level is high in comparison with past Larks Lake data, and in general Larks Lake is high in comparison to lakes in the area (Tip of the Mitt, 2013). This is likely due to its marl substrate and high buffering capacity.

Using Carlson's (1977) TSI equations we determined the TSI of Larks Lake to be meso-oligotrophic. Based on the total phosphorus levels of 6.0µg/L we get a TSI of 30, our Chlorophyll a level was 2.4µg/L, which gives us a TSI of 39 (Carlson and Simpson, 1996). Because our Secchi disk was still visible at the bottom of the lake, so we could not use Secchi depth to calculate TSI. The dissolved oxygen levels were fairly consistent throughout the water column and the bottom of the lake did not become anoxic, supporting the meso-oligotrophic trophic status previously determined (Dodds and Whiles, 2010). Marl lakes typically have low productivity (Wetzel, 1970) so it is not unusual that Larks Lake is unproductive and oligotrophic.

Light irradiance gives us an extent of productivity in the lake, and Larks Lake has productivity throughout the depth of the lake. Our Secchi disk reached the bottom of the lake before disappearing showing that the photic zone extends to the bottom (2.3m) of the lake (Dodds and Whiles, 2010). Our photometer also confirms the extent of the photic zone because it records a level of 50.3µmol at the bottom of the lake (2.3m) (Figure 9), this level is 16.9% of the surface irradiance and the photic zone extends to 1% surface irradiance (Dodds and Whiles, 2010). This depth of light penetration is common among oligotrophic lakes (Carlson and Simpson, 1996).

Temperature influences photosyntheis and the extent of the photic zone (Dodds and Whiles, 2010). The temperature of Larks Lake remains constant throughout the water column. Photosynthesis approximately doubles with each 10ºC increase (Dodds and Whiles, 2010), had the temperature changed significantly, it would have been important to measure chlorophyl a levels at different depths. DO can affect nutrient levels due to redox reactions changing but due to the consistency of the temperature, and lack of an anoxic hypolimnion there should be no significant differences and therefore we did not make separate nutrient measurements.

Dissolved oxygen (DO) changes throughout the water column is an important distinction between trophic statues, more eutrophic lakes tend to become anoxic in the hypolimnion and more oligotrophic lakes have oxygen in the bottom of the limnetic zone (Dodds and Whiles, 2010). The bottom of Larks Lake is oxic (Figure 4) and the presence of macrophytes supports this measurement. The fact that there is light penetration to the bottom of the lake supports photosynthesis and therefore the input of DO. The oxic qualities of the deepest part of Larks Lake it supports the meso-oligotrophic TSI previously determined.

Conclusion

Larks Lake is a oligotrophic lake with some mesotrophic characteristics such as higher chlorophyll a levels (Carlson and Simpson, 1996). Due to the light penetration and presence of oxygen in the profundal zone we classified Larks Lake as oligotrophic. Our fishes data supports a further increase in LWD in the lake, particularly in the littoral zone. This would help increase levels of Largemouth bass (Lawson *et. al.,* 2011) because nesting areas would increase, and because growth rates increase with increased littoral LWD (Gaeta *et. al.,* 2011). Lakeshore residential development is relatively low and the amount of natural shoreline is significant on Larks Lake. If development continues to increase on the shoreline, and natural shoreline decreases, causing a decrease in LWD input Largemouth bass populations would likely decrease (Sass *et. al.,* 2006). The local angler population of Larks Lake is already concerned with the decrease in game fishes populations, and a further decrease would be concerning to them.

However there has been an increase in large game fishes: smallmouth bass, and largemouth bass, in the last twenty years (Anderson and Ridley, 1993). This is a good sign for the relative value of the lake. The levels of nutrients are currently able to support the fishes populations of the lake, and an increase in fishes is possible with the current zooplankton density (Dai, 1997). Likely a solution that will help increase game fishes and their growth rates, but preserve the beauty of the lake is a further increase in LWD in the lake, and the stocking of bluegill planned.

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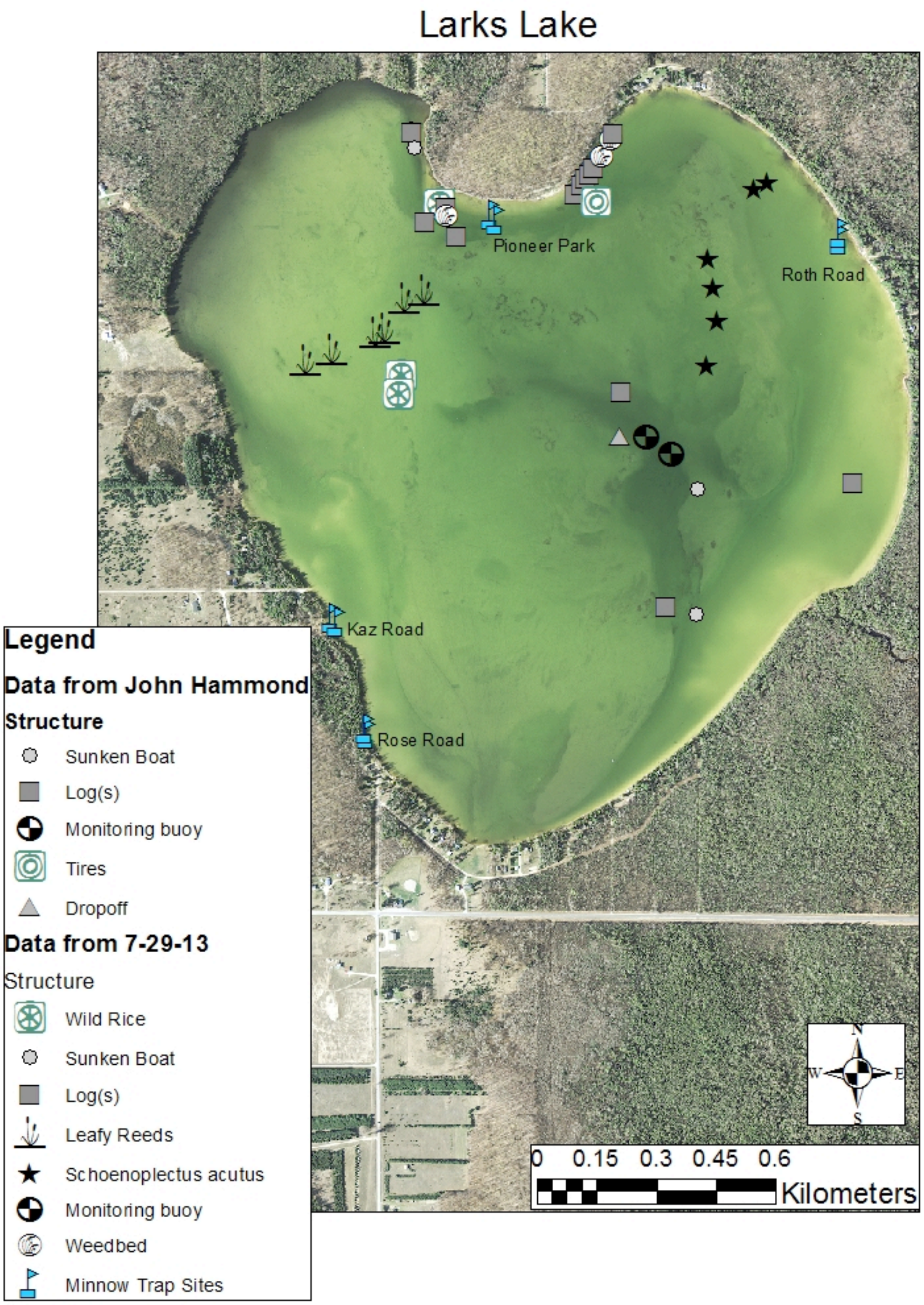

Figure 1: Larks Lake map of fish structure and minnow traps. Pioneer Park is site A, Roth Road is site B, Rose Road is site C, and Kaz Road is site D. Minnow traps were placed based on public accessibility.

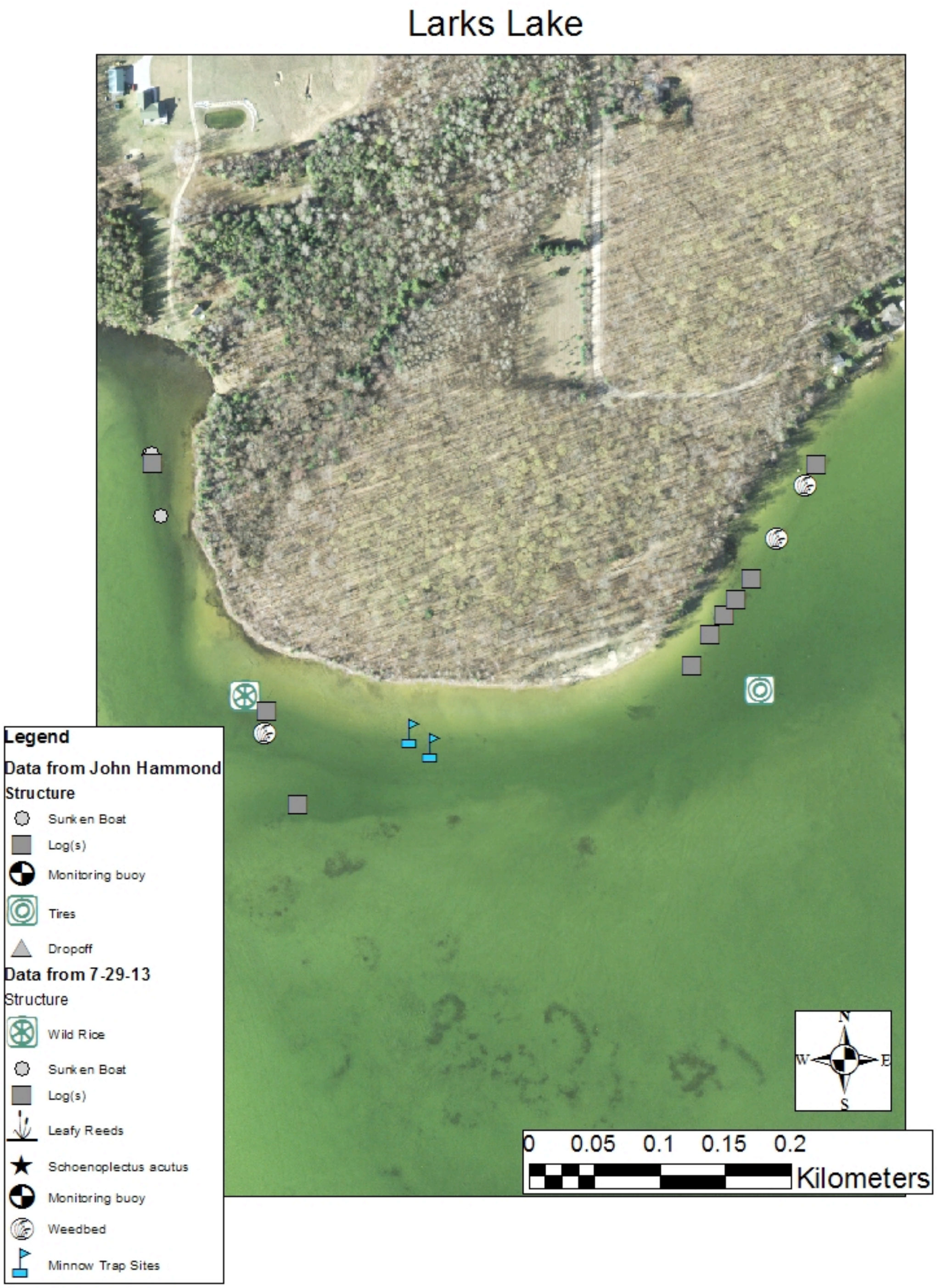

Figure 1(inset): Larks Lake map of fish structure and minnow traps, map specifically of Pioneer Park and the surrounding lake area.

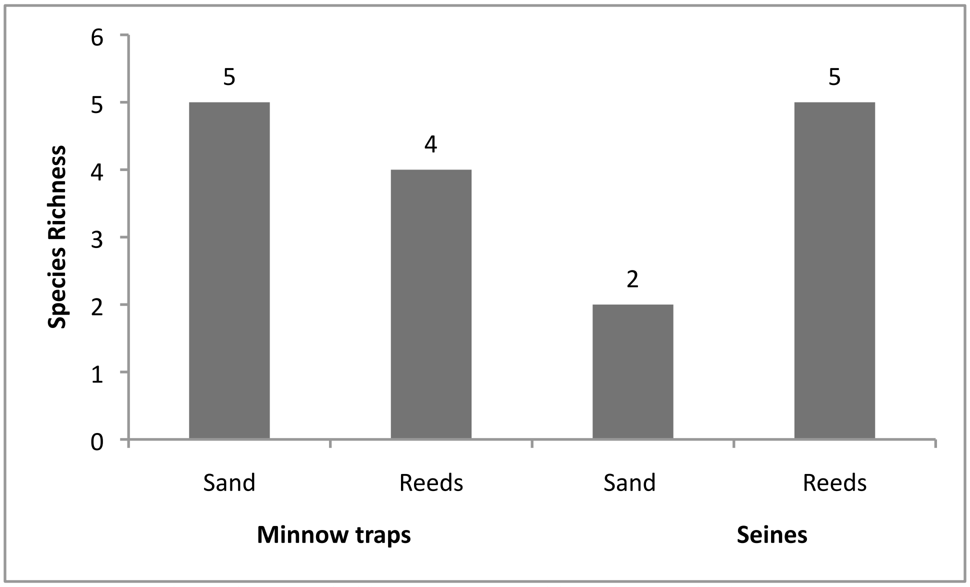

Figure 2: Species richness of habitats as measured by seines and minnow traps.

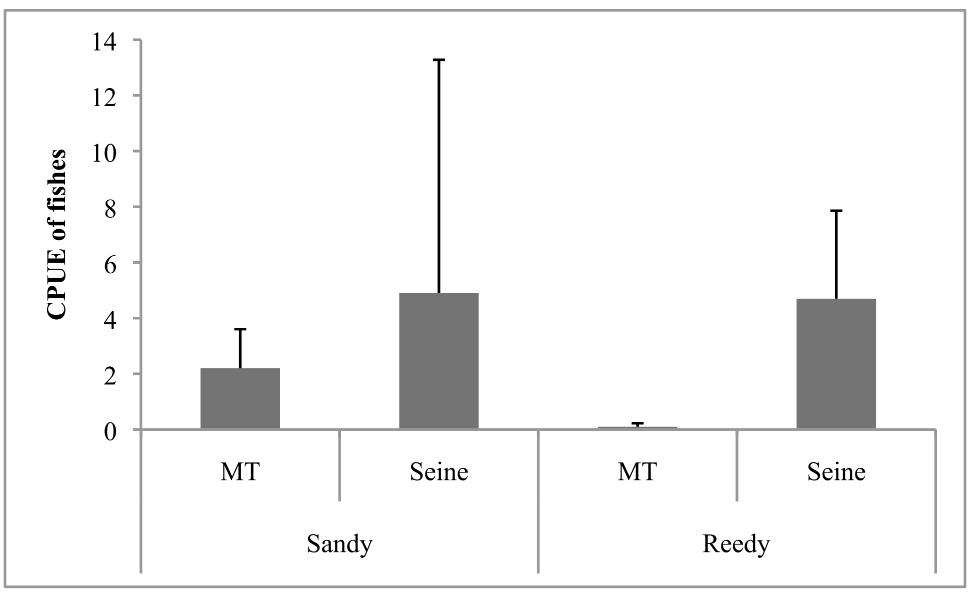

Figure 3: Average CPUE of fishes measured by fishes per 48hours for minnow traps, and by fish per meter of seine for seines.

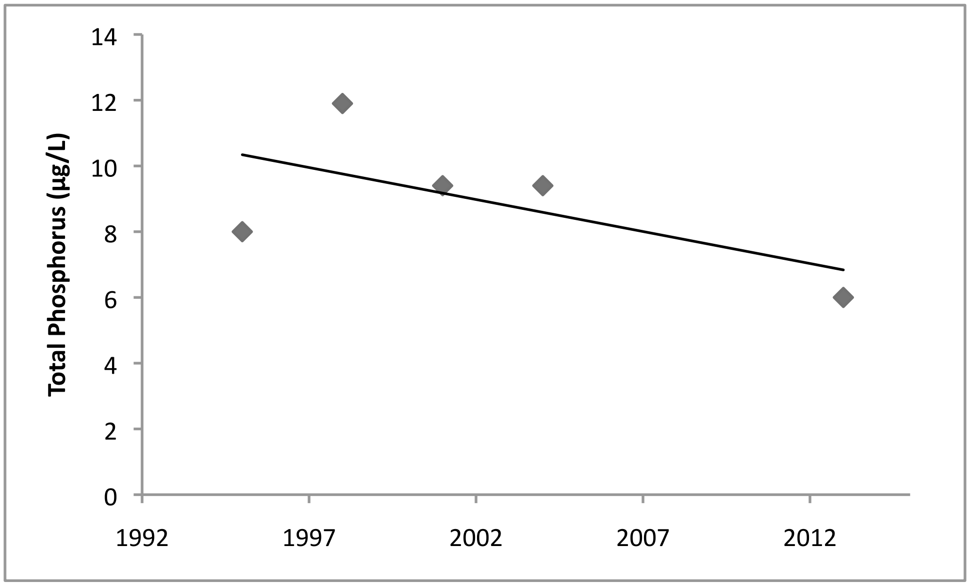

Figure 4: Total phosphorus levels, measured in µg/L, taken at the surface of Larks Lake. Data prior to 2013 courtesy of Tip of the Mitt Watershed Counsel, data taken between the months of May and August. Data from 2013 taken on July 29, 2013 at 45º36.26'N 84º55.55'W.

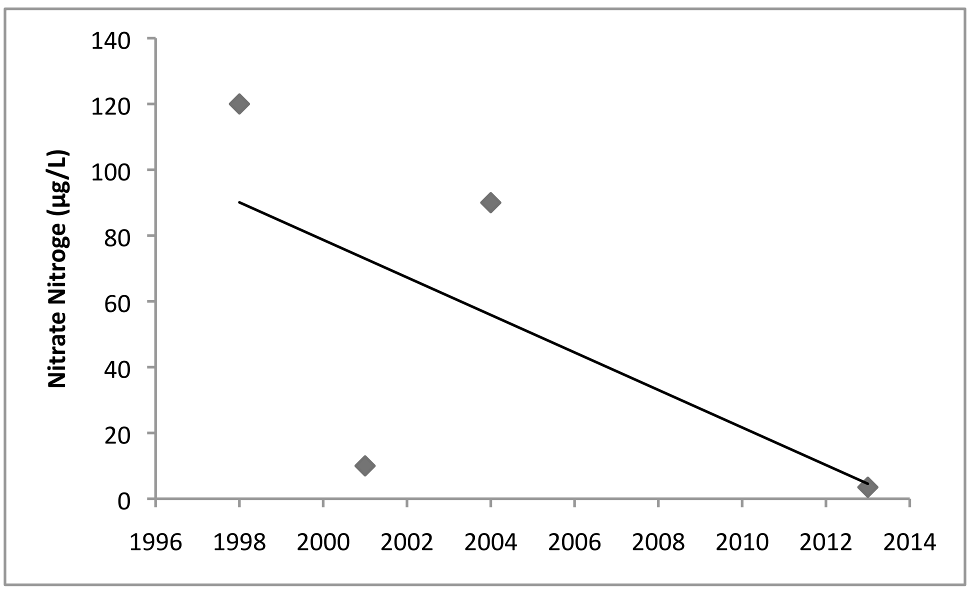

Figure 5: Nitrate (NO_3) levels, measured in µg/L, of Larks Lake taken at the surface. Data prior to 2013 courtesy of Tip of the Mitt Watershed counsel, data taken between the months of May and August. Data from 2013 taken on July 29, 2013 at 45º36.26'N 84º55.55'W.

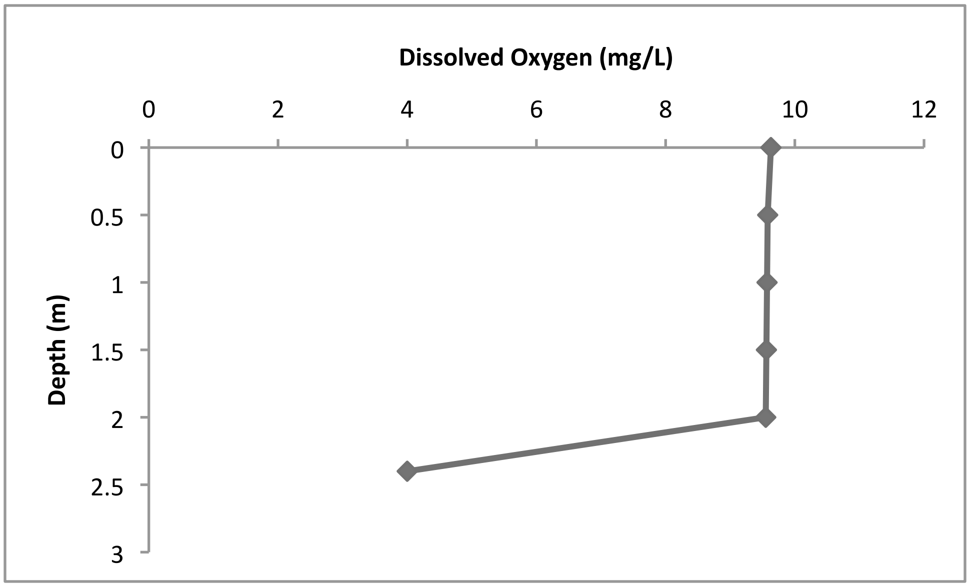

Figure 6: Dissolved oxygen levels, measured in mg/L, measured on August 3, 2013 from 45º36.26‘N 84º55.55‘W at the surface, 0.5m and every half meter thereafter.

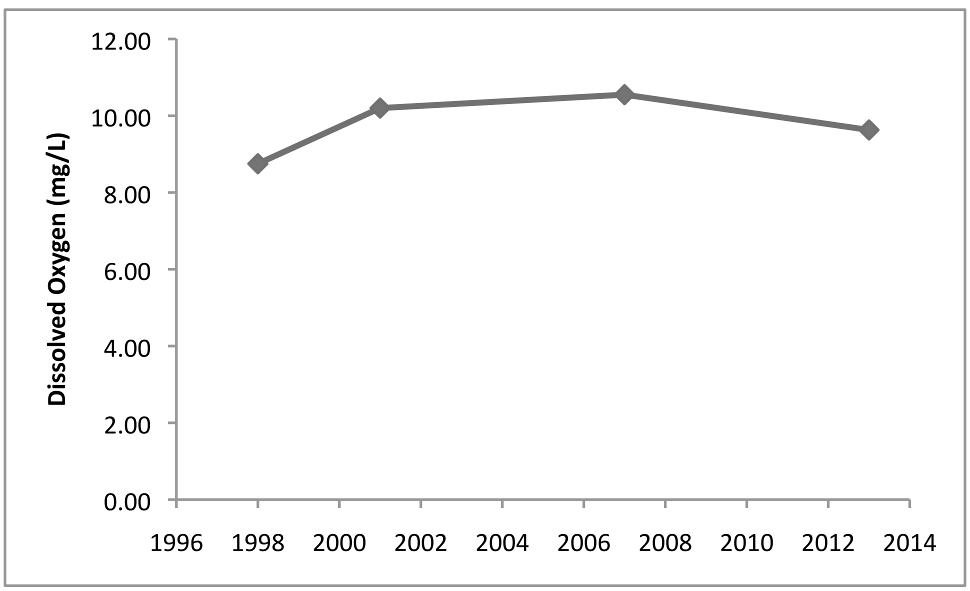

Figure 7: Dissolved Oxygen Levels of Larks Lake. Data from prior to 2013 courtesy of Tip of the Mitt Watershed Council, taken by the Volunteer Monitoring program between the months of May and August. Data from 2013 taken on 8/3/2013 at 45º36.26‘N 84º55.55‘W.

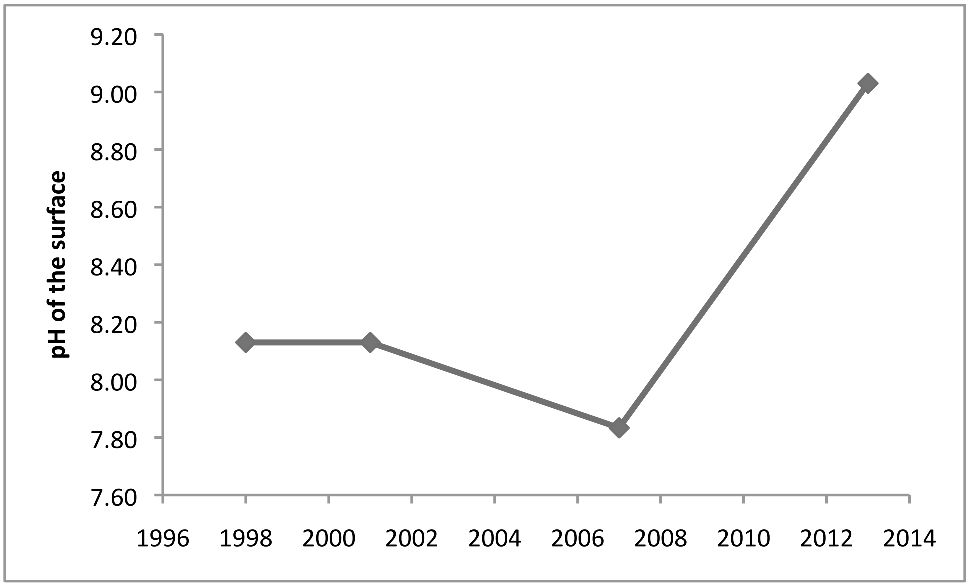

Figure 8: pH levels at the surface of Larks Lake. Measurements made prior to 2013 courtesy of Tip of the Mitt Watershed Counsel, taken between the months of May and August. Measurements made in 2013 taken at 45º36.26'N 84º55.55'W on August 3, 2013.

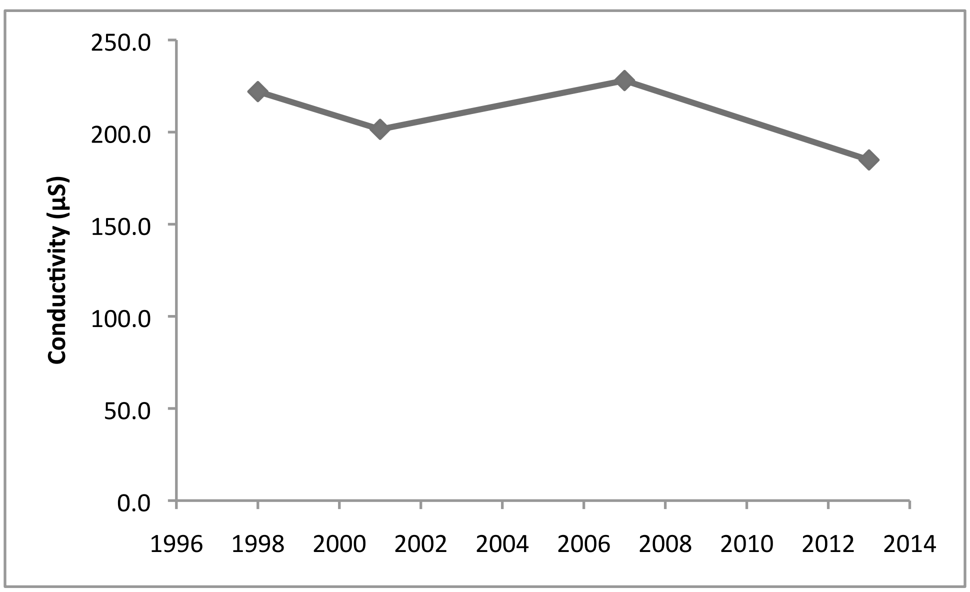

Figure 9: Specific conductivity measured in µS at the surface of Larks Lake. Measurements prior to 2013 courtesy of Tip of the Mitt Watershed Counsel, data taken between the months of May and August. Measurements from 2013 taken on August 3, 2013 at 45º36.26'N 84º55.55'W.

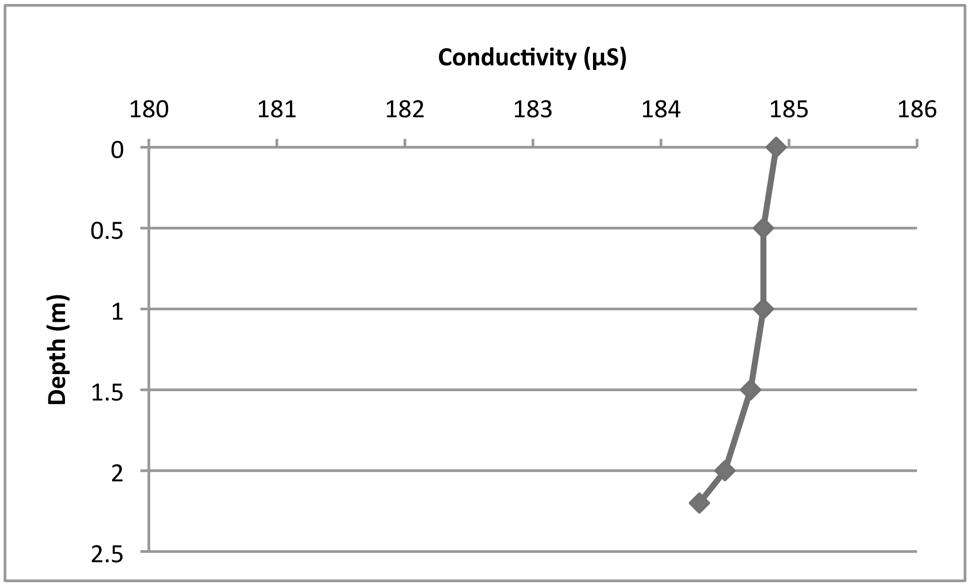

Figure 10: Specific conductivity measurements in µS of Larks Lake. Measurements made from 45º36.26'N 84º55.55'W, at the surface, 0.5m and every half meter thereafter until the bottom of the lake (2.2m).

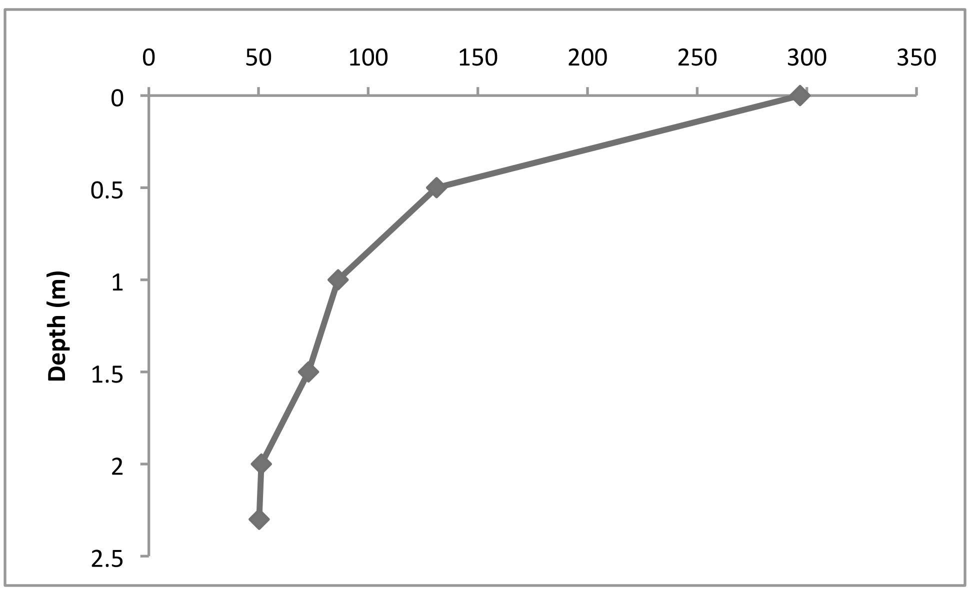

Figure 11: Photometer measurements taken at the surface, 0.5m and every half meter thereafter until the bottom (2.3m) of Larks Lake. Measurements made at 45º36.26'N 84º55.55'W.

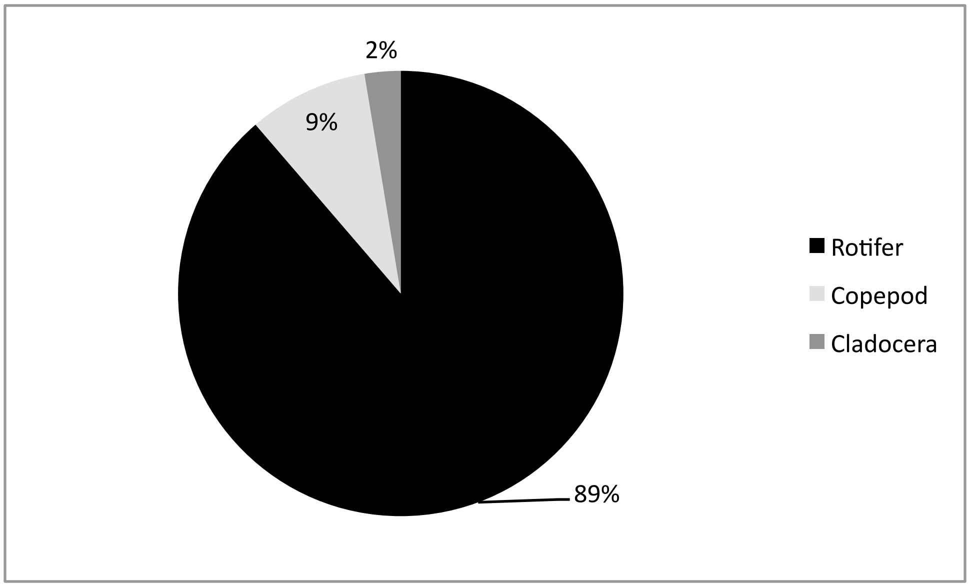

Figure 12: Abundances of zooplankton per liter of water in Larks Lake. We sampled 120.99 liters of water from the lake, across a variety of depths and structures.

Table 1: Total abundance of species caught by Anderson and Ridley (1993).

Smallmouth bass	3
Largemouth bass	2
White sucker	11
Brown bullhead	14
Pumpkinseed	1
Yellow perch	18
Common shiner	7
Bluntnose minnow	5
Banded killifish	1
Creek chub	1

Table 2: Total abundance of fishes caught at all four sites.

Spottail shiner	189
Banded killifish	1
Rock bass	5
Smallmouth bass	32
Yellow perch	74
Iowa darter	1
Largemouth bass	22